

RELATION BETWEEN TEMPERATURE, HUMIDITY AND ACTIVITY OF HOUSE MOSQUITOES*

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A search of the literature reveals the fact that comparatively little is known of the behavior of adult mosquitoes under atmospheric conditions. There are, however, a number of observations published on the relation between the behavior in general of adult insects and temperature, humidity, light, etc. A few publications which have bearing on the subject under discussion will be cited for comparison.

Headlee (3) discussing external factors which influence the flight of mosquitoes states: "Without doubt, low temperature reduces, may suspend, or even destroy, the activity of the adult mosquito. Excessively high temperature always retards mosquito activity. A warm temperature, 80° F., is extremely favorable."

"Atmospheric moisture has a powerful effect upon the adult. High percentages are favorable and low percentage deadly. Rain itself is decidedly injurious and prevents adult mosquito activity. Wind of low velocity, high temperature (about 80° F.) and high humidity appear to be the ones that favor long flights." These conclusions are drawn chiefly from field observations made by men engaged in practical mosquito control.

Chapman (1) in his study on the life history of *Taphrocerus gracilis* (Say) publishes observations made on the adult beetles which were greatly influenced by high temperature and strong light, but with low temperature they were inactive, so that they retracted their appendages and dropped from the foliage. Cook (2) considered the effect of temperature and humidity in relation to the number of moths flying at night. He employed

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the method of partial correlation to measure the effects and concludes that temperature has a positive influence on the catch at all times, but the influence is much larger below than above optimum humidity. Humidity was found by far the most important factor studied. Any increase in the 7 P. M. humidity up to about 54 per cent. tends to increase the catch, while beyond this value it decreases the catch in almost the same proportions. Shapley (7) in a study on the thermokinetics of *Liometopum apiculatum* Mayr states that as the temperature rises 30° C. the speed of the ants changes 15 fold, increasing uniformly from 0.44 to 6.60 cm. a second. In a later note (8) the same author states that at a given temperature the speed of one ant is nearly 50 per cent. greater than of another. There are apparently great differences in individual behavior and sufficient numbers of insects should be used to derive a true average. Stumper (10), publishing some results on the thermic coefficient of certain ants, states that activity is found to occur only between certain limits of temperature; these limits are variable according to the species but constant for each species. For instance, *Formica rufa* is active between 46–104° F., *Lasius niger* between 50–82°, and *Myrmica rubra* between 46–82° F. Sviridenko (9), studying the behavior of the maroccona locust under different meteorological conditions, found that larva swarms start their daily march in the morning when the temperature reaches 73–80° F. and stop whenever it drops again to the same level, whether in the evening or during the day, owing to clouds or wind. At a temperature of about 86–92° F. the swarms also cease their movement, obviously from excess of heat. Thus the movement of larvæ of the locust is due to thermotaxis.

The effect of temperature upon the locomotor activity of the boll weevil was tested by Morrill (5) who found that as temperature was gradually raised the activity of the weevils increased up to 105° F. At 95° F. the beetles were very active, at 86° they began to lose activity; and at 37° all movement ceased. Out of doors, weevil activity began and ceased at about 75°; feeding continuing at lower temperatures than oviposition. Those observations show that activity differs for different species of insects, but that within the temperature range the general behavior of the different insects is very similar.

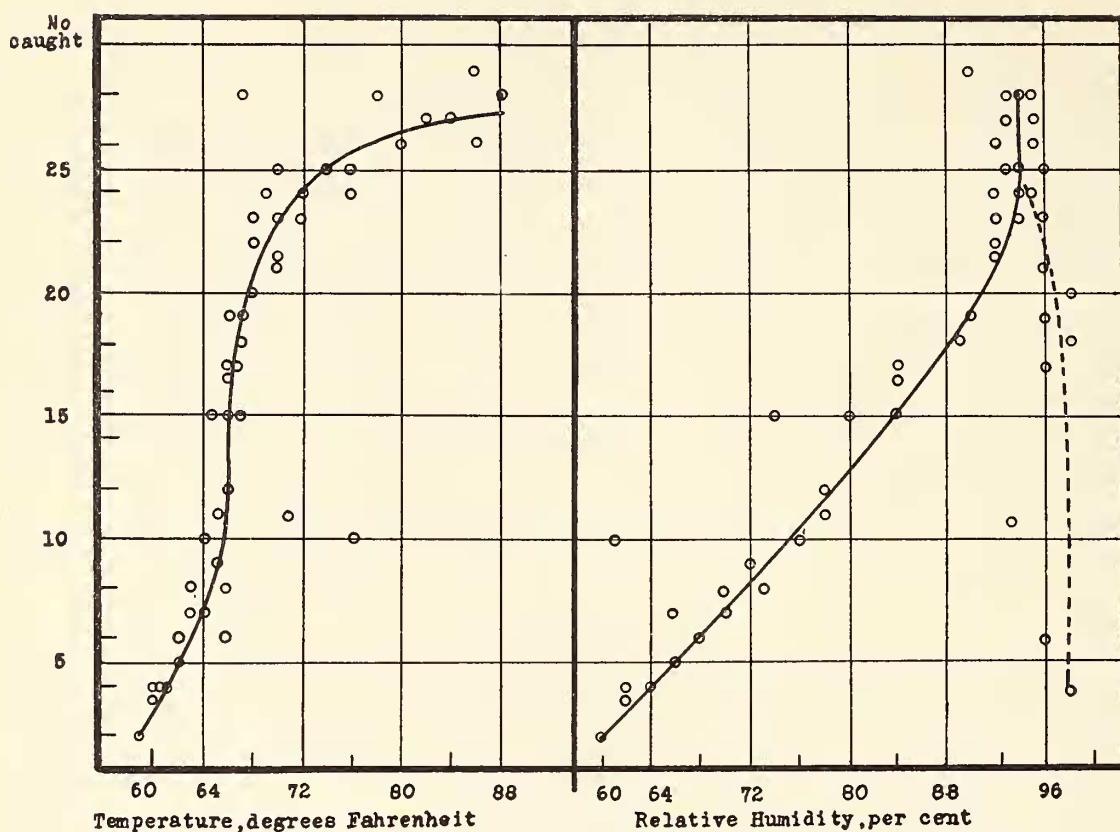
In a former publication an attempt was made by the writer (6) to find possible simple direct relations between atmospheric conditions and the behavior of the salt marsh mosquitoes, *Aedes sollicitans* and *A. cantator*. It was found that temperature at the time of observation is the deciding factor for the activities of these insects. Their activity increases with the increase of temperature unless the temperature becomes too high. A wind velocity of more than eight miles an hour overcomes the influence of temperature. The number of salt marsh mosquitoes alighting increase in almost linear fashion with the increase of relative humidity up to 85 per cent.; from 85 to 95 per cent. relative humidity, the numbers alighting remain nearly constant.

Experimental

A somewhat similar study was made during 1924 in regard to *Culex pipiens*. Mosquitoes were collected for 15 minute periods near a sewage-charged brook in Highland Park, N. J. The mosquitoes were captured alive to be used in other experiments, and the actual numbers which could have been caught by killing were consequently greater than the numbers caught alive. With increasing activity of the insects it became increasingly difficult to capture them alive, but it was observed that when a certain temperature "limit" (70°–75° F.) was reached the stimulating effect of temperature was such that much less attention was paid by the insects to the movements of the observer and it became easier to place the bottles over them without being distracted from their feeding. Nevertheless it is possible that some error obscures the actual facts around the temperature "limit."

Results

The results obtained are shown graphically in figure 1. In the first part of this figure the catches are plotted together with the temperature at the time, irrespective of other influences such as relative humidity, wind and light intensity. In the second part of the figure the numbers caught are compared with the per cent. relative humidity existing at the beginning of each collecting period. No attention is here paid to temperature. A perusal



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of the first part of the figure seems to show that a definite relation exists between temperature and the numbers of mosquitoes alighting and caught. From all my studies alighting seems to be due mainly to an increase in activity, although an increase in attractiveness of the host under higher temperatures might play a role. It can be seen from the curve that up to about 70° F. the temperature accelerates the activity of the insects greatly, but temperatures above 70° F. do not seem to increase the activities of these mosquitoes at the same rate. In this respect it is of interest to record the behavior of freshly caught *C. pipiens* females which were confined in closed glass containers submerged in water which was slowly heated to different temperatures. A condensed summary of the observations is given in Table 1.

From these notes it can be seen that below 70° F. the activity of the insects is slight (compare Chapman, Shapley and Morrill) but at temperatures between 70° and 80° F. activity increases rapidly, while at temperatures between 80° and 90° F. greater

activity was exhibited. At higher temperatures their activity becomes much less (see Sivoridenko) until at 112°–113° the insects were killed.

TABLE 1.—REACTION OF CONFINED MOSQUITOES TO TEMPERATURE

Temperature °F.	Behavior of Mosquitoes.
55	Inactive, resting.
60	Inactive, legs are moved at intervals.
65	Crawl for short distances at intervals.
70	Crawl intermittently.
74	Crawl and fly occasionally.
77	Activity increased.
80	Active crawling and flying.
82	Flying mostly.
85	Very active, nearly continuous flying.
90	Very active, flying, sing.
95	Fly with short rest periods in which trying to puncture glass (becoming uncomfortable?).
100	Extremely active, sing in very high tone.
102	Much less active.
104	Fly only occasionally.
106	Quiescence.
108	Stunned, fall on backs, move legs, recuperate when taken out.
110	All activity ceased, but revive after some time when placed in the open.
112–113	Killed.

Keeping in mind that these experiments were carried out with confined insects so that there was no chance to escape, the reactions of the mosquitoes seem fairly well to correspond with those outdoors at different temperatures.

Attention is called to the interesting shape of the curve which resembles closely the well known growth curve. The resemblance might be accidental.

If Figure 1 and the brief discussion of the temperature curve is compared with the general statements made by Headlee, it can be seen that the detailed observations are in close accord with the general observations made by field workers in the course of several years mosquito control work.

A glance at the right hand part of the figure showing the relations between relative humidity values and numbers of mosquitoes caught indicates that there also exists a direct relation between relative humidity and activity of the house mosquitoes. The relation is positive up to 90 per cent. relative humidity; from then on activity seems to be accelerated to about 94–95 per cent. humidity, followed by a sharp drop when the saturation point is approaching. The acceleration seems to be the reverse from what was found for temperature. It should be noted also that activities were apparently much less stimulated by humidity than by temperature. It is possible that humidity is of greater importance (see Cook) than these graphs show. In this respect it is extremely interesting to compare data published by Headlee (4) showing the effect of proportion of atmospheric moisture on the development of the bean weevil. A curve representing the period from egg laying to the formation of pupa gives according to this investigator "a pretty accurate idea of the effects of the different percentages of atmospheric humidity (experimented with) on the rate of development of this insect." His curve has very much the same shape as the one given in this paper for the activity of adult mosquitoes. This striking resemblance might not be so extraordinary if the activity of mosquitoes is considered from the standpoint of metabolism. An increase in metabolism is the result of an increase in the speed of chemical reactions, due to changes in temperature and moisture. Increased activity results from an increase in the speed of these chemical reactions and consequently the activity of insects might directly be compared with the development of an insect.

Summary

The 15-minute catches of house mosquitoes are compared with the temperature and per cent. relative humidity existing at the time of collecting.

The graphically shown results indicate that a close relation exists between numbers of mosquitoes caught, which is supposed to indicate activity of the insects, and temperature and also between numbers caught and relative humidity.

Summarized experiments on the behavior of confined mosquitoes at different temperatures seem in accordance with the field observations.

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ENTOMOLOGY IN ZOOLOGICA

The recent report on the Coleoptera from the Williams Galapagos Expedition by Andrew J. Mutchler in volume V, number 20, of Zoologica recalls the various other entomological papers which have appeared in this journal of the New York Zoological Society and with which entomologists should be familiar. Volume III, for instance, contains papers by Wheeler, Schwarz, Barber, Boving, Felt, Brues, Osborn and Mann, and in volume V various specialists have reported in detail upon the insects collected on the Galapagos Islands by the Harrison Williams Expedition.—ED. .